High Resolution Imaging:
Why is it Important for T1 Weighted Imaging, MRA, and SWI?

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Categorical course: Human MRI/MRS at High Static Magnetic Fields

This presentation will deal with the advantages of high field MRI in morphological and vascular imaging. We will try and address what elements of imaging are the same and what has changed in going to high field. Three different areas will be covered: low flip angle imaging to avoid high rf power deposition but maintain excellent contrast-to-noise; time-of-flight MR angiography in the brain; and susceptibility weighted imaging (SWI) at high fields.

Low flip angle spin density weighted imaging:

The ability to create high quality T1 images was a concern in the early days of high field imaging. Today it can be done with either an MP-RAGE sequence which uses an inversion pulse or with a FLASH sequence. Both have advantages. The former can do high resolution imaging of the entire brain better and faster than the conventional FLASH approach, while the latter can do whole brain coverage with lower resolution faster than the MP-RAGE sequence. We will discuss issues of bandwidth for FLASH and how structures such as the hippocampus can be beautifully imaged quickly. We will discuss issues of why collecting the data with high resolution and collapsing it back to lower resolution after reorientation is important with MP-RAGE data. Examples will be given with and without multi-channel coils and parallel imaging. New concepts, such as the presence of iron in the gray matter, and how this affects T2* in the tissues and how this in turn affects T1 imaging will also be discussed.

Theory

The approach we take is to simulate the contrast at high field using the expected and measured longer T1s for gray matter and white matter. We consider only the short TR, short TE steady state incoherent gradient echo sequence. The usual equations governing the signal for this experiment are given by:

$$\rho(\theta) = \frac{\rho_0 * \sin\theta * (1 - E_1)}{(1 - E_1 * \cos\theta)}$$

In the limit of small flip angle this becomes:

$$\rho(\theta) = \rho_0 * \theta - \frac{\rho_0 * \theta^3 * (1 + 2 * E_1)}{3 * (2 - 2 * E_1 + E_1 * \theta^2)} \text{ + higher order terms.}$$

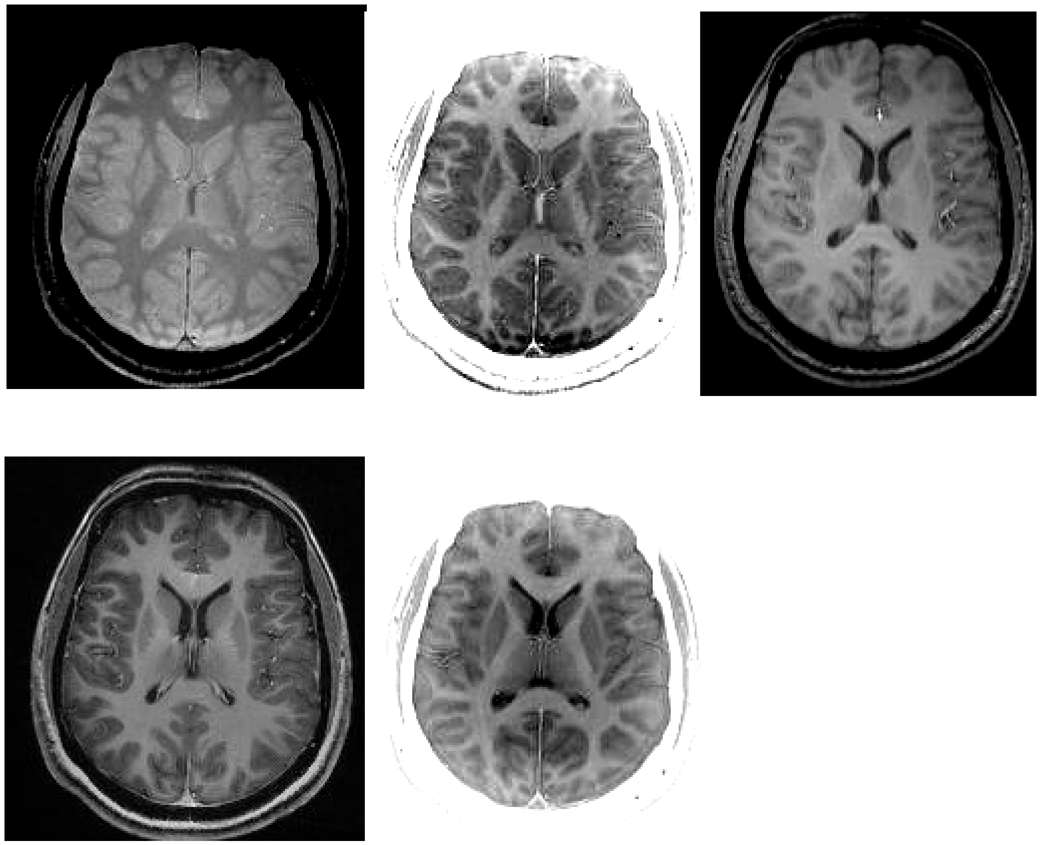

Figure 1: The 4^{o} flip angle has good GM/WM contrast which is easily see on the reversed image (Fig. 2b). Using the same sequence with a 20^{o} flip angle yields the usual T1 contrast (Fig. 2c) while the best contrast is obtained with the MPRAGE sequence (Fig. 2d). The 2^{o} flip angle reversed contrast image shows better contrast between CSF and GM while maintaining good GM/WM contrast (Fig. 2e).

MR Angiography at 4T

MR angiography also benefits from the higher SNR at high fields (1). These sequences are easy to adjust to allow for higher and higher resolution which is viable with the increased SNR. Examples are given with and without MTC pulses and with different echo times to examine the effects of the reduced T2* of gray matter. It is suggested that a resolution of 0.5mm x 0.5mm x 1.0mm is easily achievable and should be the standard in the field at 3T and higher field strengths.

Figure 2: A high resolution time-of-flight MR angiogram collected with MTC. The resolution is 0.25mm x 0.25mm x 1.0mm. Imaging parameters were: TR = 72ms, TE = 5.66ms, FOV = 256mm, and iPAT = 2.

Susceptibility weighted imaging

Susceptibility weighted imaging (SWI) is a new means to image vascular disease (2). It is used today in better studying trauma (3), stroke, tumors and occult vascular disease. At lower fields the coverage, speed of acquisition and SNR is limited. Higher fields offer faster SWI data acquisition, whole brain coverage and excellent SNR so that 0.5mm x 0.5mm x 2mm resolution is possible. Small veins on the order of a few hundred microns can be seen easily at 3T and 4T. High field also makes visualization of iron content in different structures in the brain more viable.

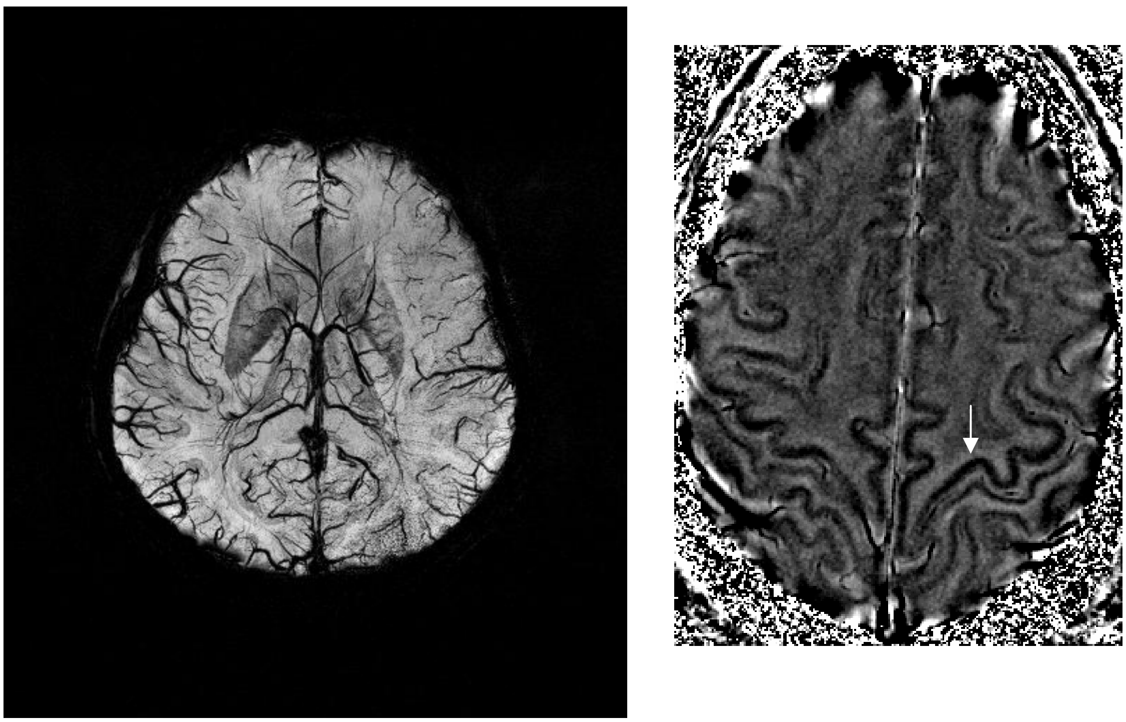

Figure 3: Left hand image: An SWI image projected through 2cm of the brain with a resolution of 0.5mm x 0.5mm x 2mm. Right hand image: An SWI filtered phase map showing the high iron content in the motor cortex.

References:

1. Bernstein MA, et al. High-resolution intracranial and cervical MRA at 3.0T: technical considerations and initial experience. Magn Reson Med. 2001;46:955-62.

2. Reichenbach JR, et al. Small Vessels in the Human Brain: MR Venography with Deoxyhemoglobin as an Intrinsic Contrast Agent. Radiology 1997;204:272-277.

3. Tong, KA, et al. Improved Detection of Hemorrhagic Shearing Lesions in Children with Post-traumatic Diffuse Axonal Injury – Initial Results. Radiology 2003;227:332-339.